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Evaluation of the Economy of Energy Storage or Grid Enforcement in Low-Voltage Distribution Grids with a High Degree of Decentralized Generation

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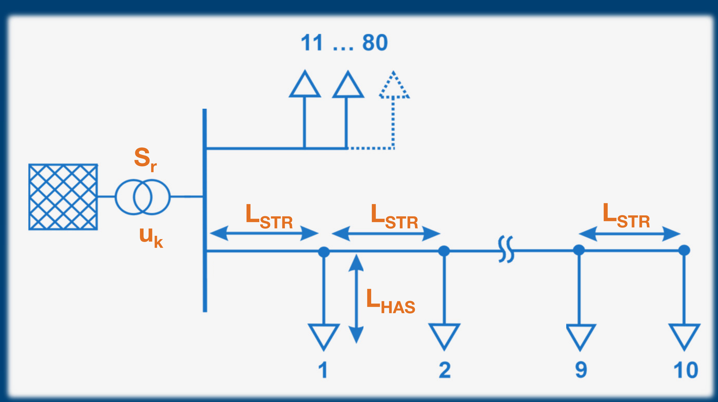
Low-voltage reference networks

The simulations are based on statistically firm **reference networks for low-voltage distribution grids**. These typical networks have similar characteristics to approx. 50 % of real distribution grids (see [1]).
Instead of a variety of real networks, only few typical reference networks must be examined in order to obtain reliable conclusions.

The attention was mainly directed towards **suburban areas**, **villages** and **rural areas**, which are most critical for PV feed-in.



Potential of roof-mounted PV power plants

The usable surface area on rooftops of different regions was statistically evaluated in [2]. According to these results the **average photovoltaic potential** of each settlement type can be estimated:

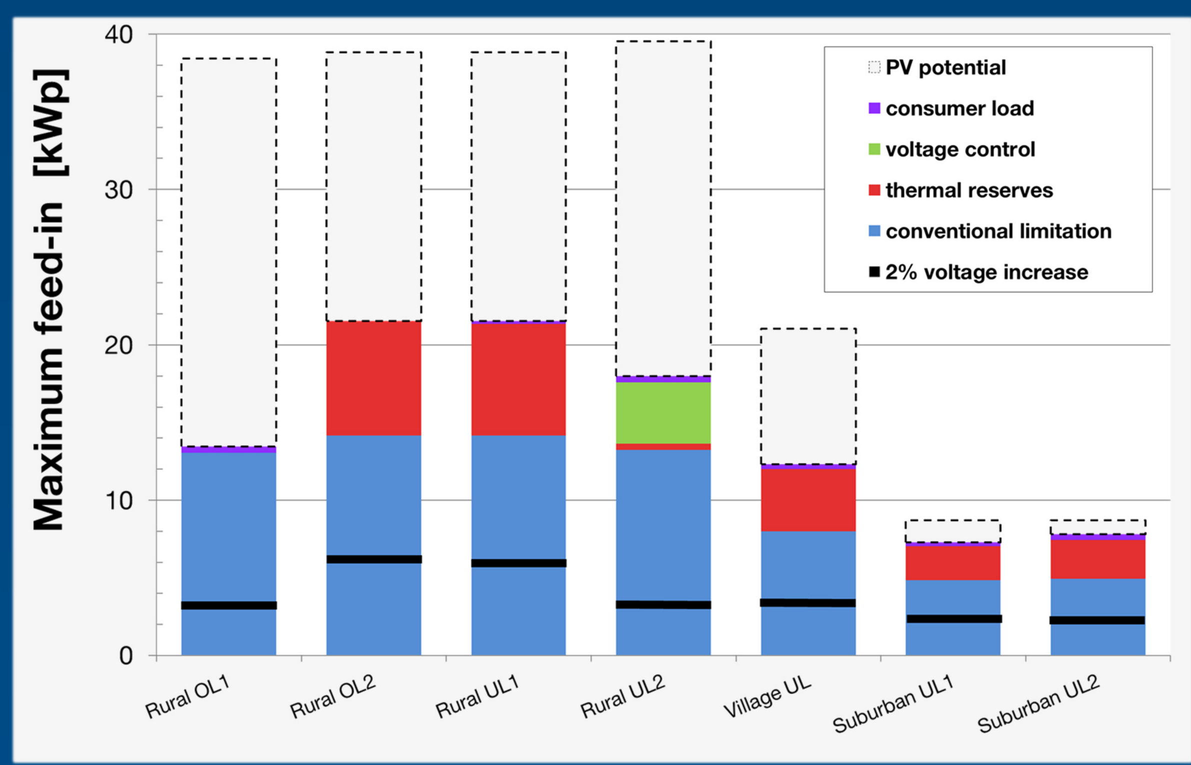
average PV potential	rural area	village	suburban
residential buildings	13,7 kW_p	12,5 kW_p	8,7 kW_p
agricultural buildings	53,9 kW_p	47,3 kW_p	-

The impact of an increasing decentralized feed-in was examined using a commercial simulation program. At each rooftop a photovoltaic power plant was assumed.
Its nominal power was gradually incremented up to the maximum potential.

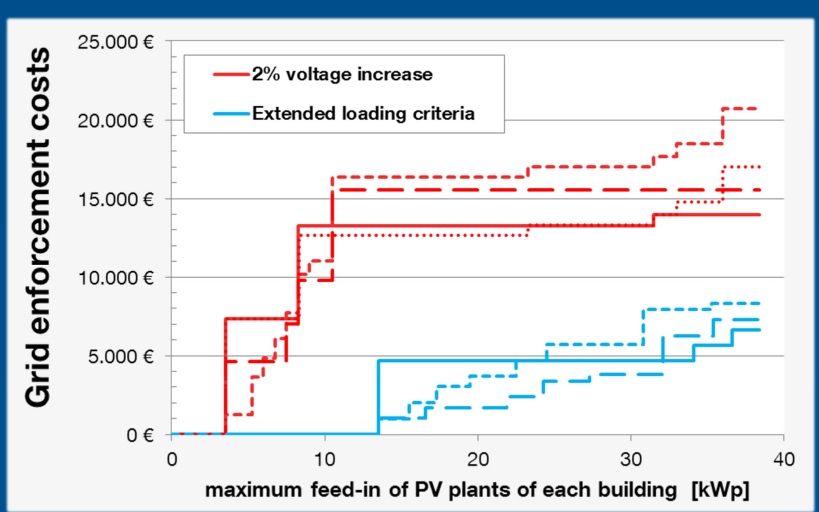
Limits of grid transmission capacity of low-voltage distribution grids for decentralized generation

Limitations of the grid transmission capacity of low-voltage distribution grids:

- Voltage increases due to fast load and generation changes have to be less than 2 % of the nominal grid voltage U_N on each connection point (VDEW recommendation).
- **Conventional limitation criteria**:
  - The loading of each transformer is less than its rated apparent power S_{Tr}.
  - Distribution lines can be loaded till their thermal limiting current I_{th}.
  - Voltage increases/decreases are limited to a maximum of ±10 % of the nominal grid voltage U_N.
- To increase the permissible feed-in of PV plants the following measures for **extended limitation criteria** can be taken into account:
  - Thermal reserves of the transformers can be used till 150 % of its rated apparent power S_{Tr} .
  - In case the permissible voltage rise is exceeded, reactive power compensation of the inverters in addition to the active power feed-in could be integrated.
    By forcing a feeding with $\cos(\varphi) = 0.9_{ind}$ the voltage rise in the grids can be reduced successfully.



Grid enforcement costs



Grid enforcement costs per PV power plan in a typical reference network depending on the PV feed-in.

It is not possible to integrate the entire potential of photovoltaic power plants in the low-voltage distribution grids at present. The distribution networks have to be strengthened to increase the permissible feed-in of PV plants.

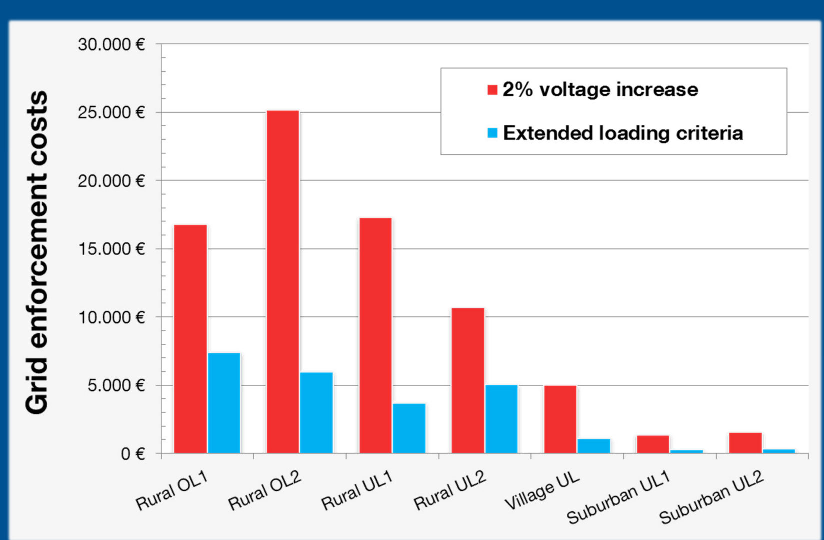
The necessary **grid enforcement costs** for the complete integration of the existing photovoltaic potential were calculated based on typical grid elements for each reference network.

Therefore two different scenarios of grid enforcement were examined:

- **Minimisation of the present costs** (dashed lines).
- **Minimisation of the overall costs** (continuous lines)

These measures are calculated separately for:

- **2% voltage increase**
- **Extended loading criteria**

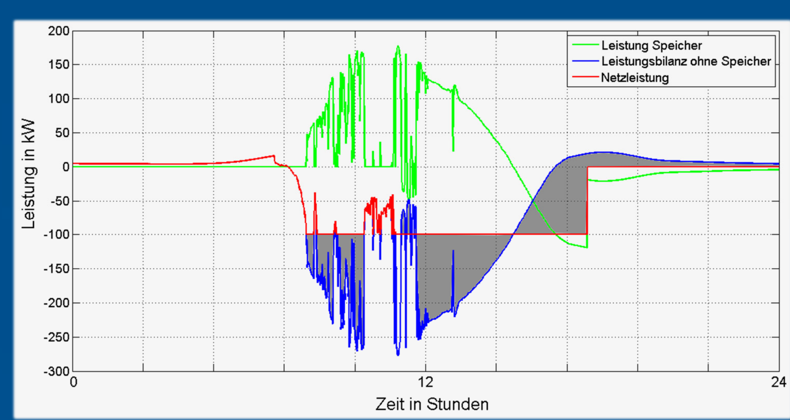


Average grid enforcement costs for each PV power plant in the reference networks up to the maximum PV potential.

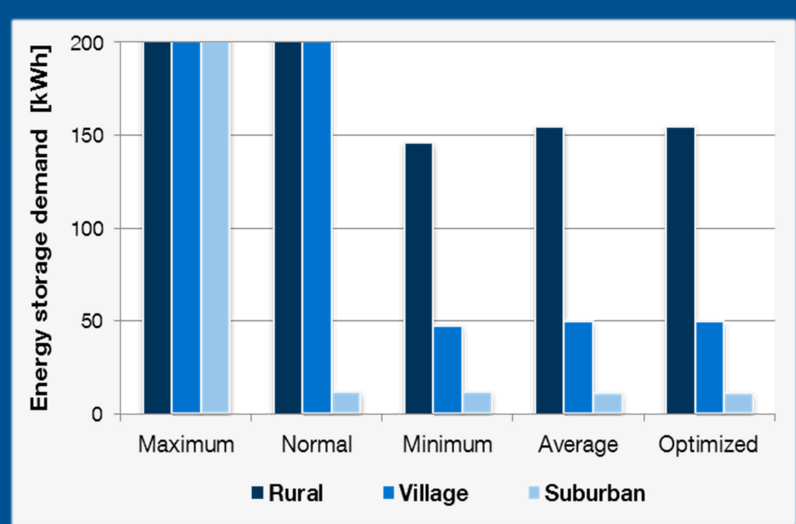
Decentralized energy storages

Local energy storages, which save the surplus generation, can be an alternative to grid enforcement and can be essential for a stable and efficient energy network in the future.

The minimal storage capacity necessary to fully integrate the photovoltaic plants is being calculated for each reference network.
In this context different approaches are made to minimize the required storage capacities.



Course of a day for the optimized usage of decentralized energy storages



Minimal storage capacity of distributed energy storages necessary to fully integrate the photovoltaic plants

The concept uses **optimization** and **forecast methods** to reduce the required storage capacity and to enhance the **self-consumption** of the local energy generation at the same time. Therefore **estimations** of the local energy consumption of the customers and the assumed energy feed-in of the PV power plants can lead to a lower amount of energy that has to be purchased. On account of this local **weather forecasts** will be interpreted as well as the feed-in of the decentralized photovoltaic plants of the past few days.

References:
[1] Kerber, Georg; Witzmann, Rolf: ***Statistische Analyse von NS-Verteilungsnetzen und Modellierung von Referenznetzen***; ew, Jg. 107 (2008), Heft 6, S. 22 -26
[2] Lödl, Martin; Witzmann, Rolf: ***Abschätzung des Photovoltaik-Potentials auf Dachflächen in Deutschland***; 11. Symposium Energieinnovation, Graz/Austria, 2010

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